Study and Analysis of Fabrication and Properties of Sand Lime Bricks

By

Ahmad Hussaini Bin Hamdan

Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Mechanical Engineering)

JULY 2010

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

Study and Analysis of Fabrication and Properties of Sand Lime Brick

by

Ahmad Hussaini Bin Hamdan

A project dissertation submitted to the
Mechanical Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(MECHANICAL ENGINEERING)

Approved by,

____

(Ir. Dr. Masri Baharom)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
December 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

AHMAD HUSSAINI BIN HAMDAN

ABSTRACT

The main purpose of this report is to document the author's finding, activities and the progress work that had been done in Final Year Project. The project entitles "Study and Analysis of Fabrication and Properties of Sand Lime Brick". Briefly the project is to study the process of making sand lime brick but with using powder processing root as the method of making the sample. The result of the experiment may vary from the ASTM requirement for sand lime brick. As for the compaction pressure and sintering temperature, the result has shown improvement as increasing compacting pressure will increase green density and decrease porosity of sample. As sintering temperature experiment, the result shown as increase the sintering temperature will increase sintered density and decrease porosity in the sample. It is due to the change in the properties of mixture of silica sand, quicklime and water. As compared to ASTM requirement for Sand Lime brick, the compressive strength is high while water absorption is less than the standard requirement. As conclusion, it proves that increase compacting pressure and sintering temperature can affect the properties of sand lime brick.

ACKNOWLEDGEMENT

First and foremost, heartfelt appreciation outstretch to parents, Mrs. Salamiah bt. Sharin for always being there when in need. Their guidance, love and emotional support are highly appreciated.

Uncountable appreciation extended to Ir. Dr. Masri Baharom for being a gratifying supervisor with kind guidance, practical criticism and valuable advice throughout the project duration of 28 weeks.

Great big thanks also extended to other family members and fellow friends who had in one way or another contributed to the success of this report.

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Project Background

The basic purpose of this project is to study the effect of compacting pressure and drying time and temperature in the process of making sand lime bricks. Sand Lime Brick has been widely used as a construction material since long time ago.

According to Industrial Studies & Purveys Unit (1970),

> Sand-lime bricks are bricks manufactured from sand, lime and water. They are white or tinted, strong, durable, light in weight and non-efflorescent. The bricks can be used for all types of building constructions and for all kinds of masonry, such as underground, exterior and interior walls or as decorative facings. It is because of these qualities inherent in sand-lime bricks that it has become more popular in use, particularly in the Western countries.

Sand Lime brick is made generally by mixing a calcerous binder with a sand filler material which is a silicate-containing mineral, after which water is added to the mixture (Gordon etc. al (1967). The mixture is mixed with a specific ratio that will affect to the quality of the sand lime bricks. . The afterwards process of the sand lime bricks are “these materials are mixed pressed and hardened under steam pressure” (Industrial Studies & Purveys Unit (1970)).

Figure 1: Sand – Lime Brick

Figure 2: the application of Sand – Lime Brick

1.2 Problem Statement

Nowadays, there is abundance of sand material available in this world especially in the Middle East but its application is very limited. Sand is dominantly used to fabricate transparent glasses and use as raw material for construction. Sand also used to make brick for construction matter. Usually, the sand-lime brick is made by using the mixture of sand and lime that will be compressed and cured. Thus considering if the various compacting pressure and drying temperature that will affect the properties of the sand brick; either it is improving or not, compared to the old method of making sand bricks, this study shall be made.

1.3 Objective

- To study the effect of various compacting pressure and sintering temperature in Sand-Lime brick fabrication process.

1.4 Scope of Study

- Determine the important properties of a sand brick.
- Determine the material properties that will be used throughout the project.
- Determine the ASTM standards and testing method for sand bricks.
- Determine the methods in producing sand bricks.
- Proper assumptions shall be made to ease the project's studies and at the same time, optimize the data integrity
- Analyze both current sand brick and the new sand brick based on ASTM standards tests.
- Provide data and figures of the new bricks properties.
- Execute proper data comparisons between the current bricks and the new brick
- Compare the gained data with other studies made previously

1.5 Relevancy of Project

This project is generally involving engineering software and lab equipment to produce and test of new prototype in order to determine the data which is the result of this project. This project is basically producing a new type of bricks in an easier producing method by using the material which can be found around of us. Furthermore, this study is important since it is important as to establish the findings on the influences of new method and using sand around us in making sand bricks to the brick's properties itself.

CHAPTER 2

LITERATURE REVIEW

2.1 Process of making Sand-Lime Bricks

According to Immo H. Redeker (1969)

> Sand lime brick are manufactured by mixing of quicklime of hydrated lime and high silica in a ratio of 85 – 95 % of sand and 5 - 15 % lime and with adjusting of moisture for good hydration and for easy pressing and forming. The mixture is then being pressed at 4000 – 8000 psi and steam cured in autoclaves at pressure reach up to 275 psi for period of 4 – 5 hours.

There are basically 5 steps in the process of manufacturing Sand-Lime Bricks. The steps are explained by the flow chart below.

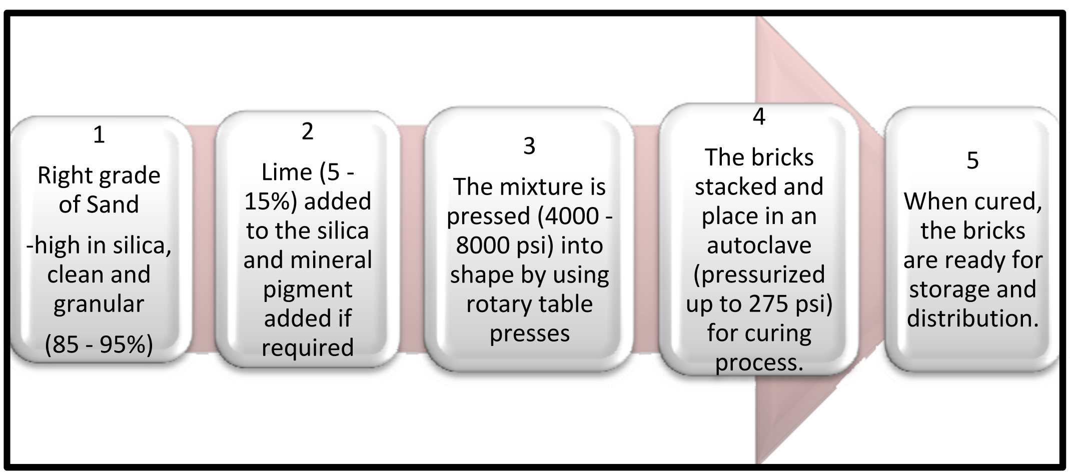


Figure 3: 5 Steps Manufacturing Sand-Lime Bricks

The picture below shows the sand-lime brick plant schematic from the first process till the final process. The number shown in the picture is based on the basic process of making sand-lime brick as in the Figure 1.

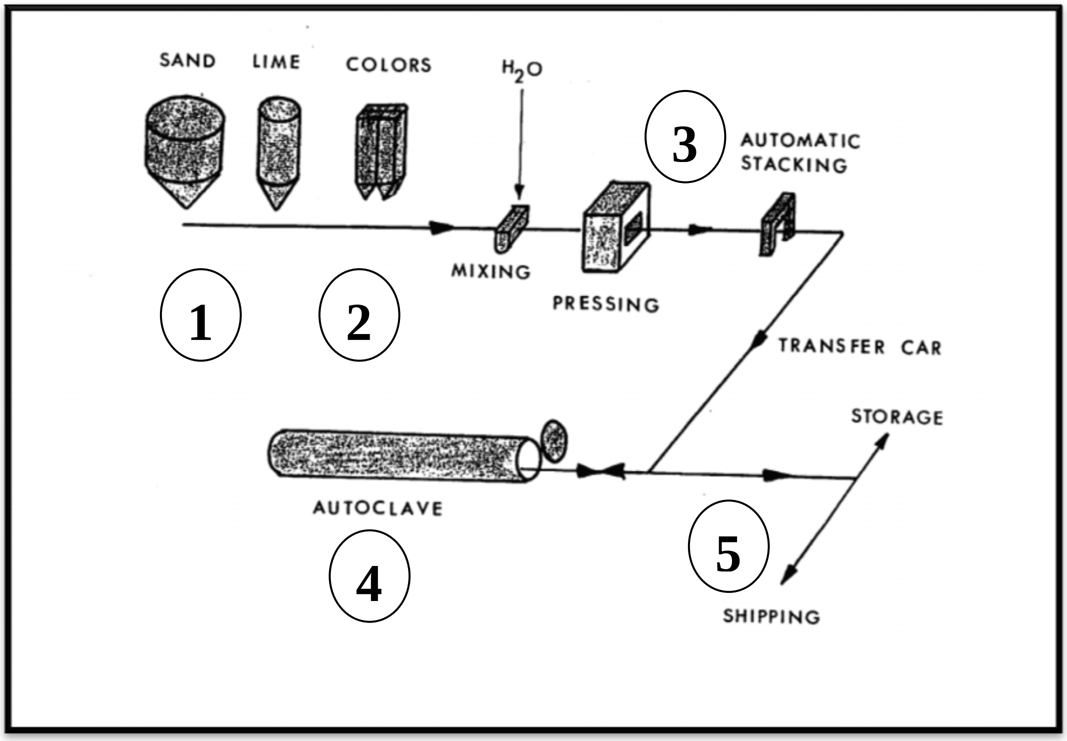


Figure 4: Sand Lime Brick Plant Schematic

2.1.1 Sand

Sand is the major component of material that will need to produce sand lime brick. Immo (1969) says that Sand lime brick are manufactured by mixing of quicklime of hydrated lime and high silica in a ratio of 85 – 95 % of sand and 5 – 15 % of quicklime. Sand contained a mineral called Silica (SiO_2). The amount of silica in the sand will affect the quality of the sand lime brick. Industrial Studies & Purveys Unit (1970) says that there are a calcium silicate brick manufactured from raw materials with a low content of SiO2, sand with a SiO2 content of more than 60% is preferred. Based on that, the amount of silica in the sand is preferred to be more than 60%.

2.1.2 Lime

Lime is used as a binding agent (Industrial Studies & Purveys Unit (1970)). Lime contains a mineral called Calcium Oxide (CaO). Lime used must have a CaO contents between 70 – 95 % and content of Magnesia (MgO) should not exceed 1.5% (Industrial Studies & Purveys Unit (1970)).

2.1.3 Water

Water (H_2O) is one of the components in producing the sand lime brick. Any well water or river water can be used to be added to the mixture as sea water and brackish water is not suitable for the process (Industrial Studies & Purveys Unit (1970)).

2.1.4 Mixture

Sand, Lime and water are required for the slaking process must be dosed in specific proportions and intensely mixed with one another (Industrial Studies & Purveys Unit (1970)). The proportion of the mixture will be the most important since it will affect the quality and properties of the sand lime brick.

2.1.5 Compacting Pressure

Presses are provided to produce true-to-size, stable and sharp edged unfinished bricks from the loose mixture (Industrial Studies & Purveys Unit (1970)). The moist sand lime mixture is pressed at 6000 – 8000 psi Immo (1969). There is no specific compacting pressure stated in sand lime brick making process.

2.1.6 Autoclaved

Autoclaved is the last process of making sand lime brick.

According to Industrial Studies & Purveys Unit (1970)

> The autoclaved is closed off by means of quick-action closure on both sides and 16 *atm*. saturated steam will be charged into the brick car-filled hardening vessel that will heats the bricks to the steam temperature for approximately 1 hour. The process of hardening is influenced by pressure, temperature and moisture and the calcium hydrosilicate is produced from the silicic acid of the sand and the calcium hydroxide during the approximately 4 hours hardening exposure. This formation of calcium hydrosilicate occurs substantially between the contacting faces of the individual limed mantled sand grains. This results in a fine and narrow-meshed lattice of extremely hard calcium hydrosilicate which gives the bricks their high crushing strength.

Basically, the autoclaved process is to make the mixture of sand, lime and water to get stronger and can withstand with high crushing strength.

2.2 ASTM Standards

According to ASTM Standards, Vol. 04.02 C73-99A, Standard specification for Calcium Silicate Brick (Sand Lime Brick)

> There are 2 grades of brick which are
>
> i. Grade SW – Brick intended for use where exposed to temperature below freezing in the presence of moisture.
>
> ii. Grade MW – Brick intended for use where exposed to temperature below freezing but unlikely to be saturated with water.

From the standards, the brick shall conform to the physical requirement for the grade specified, as prescribe in Table 1.

Table 1: Physical Requirement of Sand-Lime Bricks

Designation	Compressive Strength,psi(MPa), (brick tested flat wise) average gross area		Water Absorption max (lb/ft3) kg/m3
	Average of 3 Bricks	Individual Brick	
Grade SW	5500 (37.9)	4500 (31.0)	15 (240)
Grade MW	3500 (24.1)	3000 (20.7)	18 (288)

There are 2 types of testing method specified in ASTM C 73-99a in testing Sand-Lime Bricks which are

i. Compressive Test
ii. Water Absorption Test.

Compressive Test

i. 3 - 5 bricks will be crushed to determine the average compressive strength.

Water Absorption Test

i. 3 – 5 bricks will be submerged for 24 hours in water at room temperature and 5 hours in boiling water.

CHAPTER 3

METHODLOGY

3.1 Process Flow

This project is lab-experiment based project. The entire result can only be gained by doing the lab experiment. The project is contain several important steps which is the defining problem and identification, research regarding the topics, literature review, processing the material, data analysis and result. The entire steps can be seen in the flow chart named Figure 7.

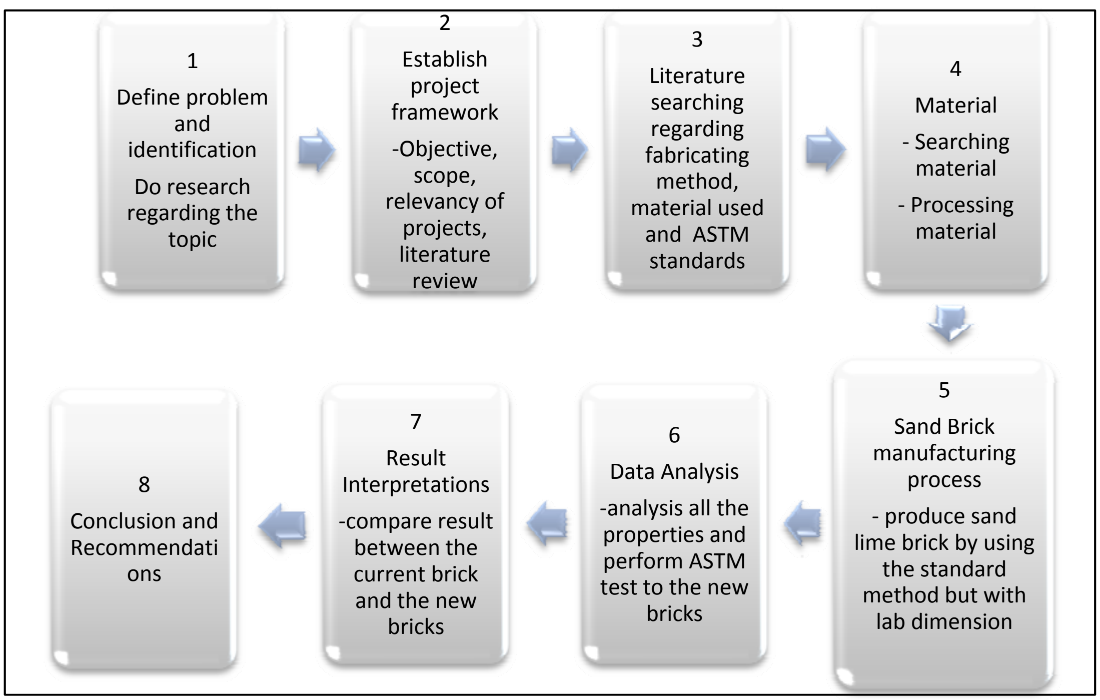


Figure 7: Flow Project

The flow of project is been explained by the entire steps in the Lab Experiment Methodology below.

3.2 Lab Experiment Methodology

Searching Material

1. Search sand (Appendix A Figure 8) and quick lime (Appendix A Figure 9) to be used in lab experiment.
2. Send sand and quick lime for XRF Analysis (Appendix A Figure 10) to get the elemental and compound percentage of material.

Processing Silica Sand

3. Grind sand using Mortar Grinder and Ball Mill machine (Appendix A Figure 11 & 12) to reduce the particle size of the sand.
4. Sieve sand by using Sieve machine (Appendix A Figure 13) to get the average size of sand particle to ~ 150μm.

Sand Lime Brick Fabricating Process

5. Mixed sand, quicklime and water by using mixer (Appendix A Figure 14) with the specific composition as shown in the Table 2.

Table 2: Mixed composition of Sand Lime Brick

Test	Silica Sand (wt%)	Quicklime (wt%)	Water (wt%)
1	76	13	11

6. Scaled and compressed 1 gram of mixture by using Auto Pallet machine (Appendix A Figure 15) at various pressures range from 6000 psi (41.37 MPa) to 16000 psi (110.32 MPa) with increment of 2000 psi.

7. Scaled (Appendix A Figure 16) and calculated green density of the compressed mixture.
8. Plot graph Green Density vs. Compacting Pressure.
9. Find optimum compacting pressure producing maximum green density.
10. Based on result of process no. 5, the compressed mixture will be sintered in the furnace at temperature range from 200^{o}C to 1200^{o}C.
11. The sintering process will be in the furnace at various temperatures for 1 hour and 5^{o}C cooling rate.
12. Scale and calculated sintered density of the products.
13. Plot Sintered Density vs. Sintering Temperature.
14. Find optimum sintering temperature producing maximum sintered density.

<u>Data Analysis</u>

15. Based on result from process no. 14, the sand-lime brick will be testing for compressive test and water absorption test.

<u>Result Interpretation</u>

16. Compare result of process no. 15 with the ASTM standards for Sand-Lime bricks.

This project has been divided into 2 parts which is the first experiment is to test the effect of compacting pressure in the process of producing sand lime brick and the second experiment is to test the effect of sintering temperature in the process of making sand lime brick. The bricks will be test for the compressive and water absorption and comparing with ASTM standards.

3.3 Gantt Chart / Milestones

Gantt chart FYP 1

Table 3: Scheduling for Final Year Project 1

No	Detail / Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Selection of Project Topic	■	■						Mid-semester break							
2	Project Identification and Planning		■	■												
3	Preliminary Research Work		■	■	■											
	Standards and Procedure		■	■	■											
4	Submission of Preliminary Report				▲											
5	Project Work				■	■	■	■								
	Further research and study				■	■										
	Literature review					■	■									
	Searching Material						■	■								
	Processing Material						■	■								
6	Submission of Progress Report									▲						
7	Seminar									▲						
8	Project work continues									■	■	■	■	■	■	■
	Learn Sand Lime Brick Fabricating Process									■	■	■	■			
	Learn machine to be used									■	■	■	■			
	Initial experiment and result												■	■	■	■
9	Submission of Interim Report Final Draft															▲
10	Oral Presentation									During study week						

▲ Milestone

■ Process

Gantt chart FYP 2

Table 4: Scheduling for Final Year Project 2

No	Detail / Week	1	2	3	4	5	6		7	8	9	10	11	12	13	14
1	Material preparation	■						Mid-semester break								
	Compaction Pressure Experiment	■	■	■	■											
2	Submission of Progress Report 1				▲											
3	Temperature Experiment				■	■	■									
4	Submission of Progress Report 2									▲						
5	Seminar									▲						
6	Temperature Experiment								■							
	Compressive Test									■	■	■	■	■	■	■
	Water Absorption Test									■	■	■	■	■	■	■
7	Poster Exhibition												▲			
8	Submission of Dissertation Final Draft															▲
9	Oral Presentation								During study week							
10	Submission of Dissertation								7 days after oral presentation							

▲ Milestone

■ Process

CHAPTER 4

RESULT AND DISCUSSION

4.1 Mixture Composition

The compositions that were chosen are 76wt% sand, 13wt% quicklime and 11wt% water based on the journal of Possible Production of Calcium Silicate Building Products from Feldspar Plant Tailing, by Immo H. Redeker, October 1969. From the journal, the composition is recommended and still not the best composition of making sand lime brick. The purpose of using this composition is to try and if there is more time, the other composition will be experimented.

4.2 XRF Analysis

The sample of sand taken from UTP's lake has been sending for the XRF analysis to analyze the elemental and compound of 2 materials that will be used throughout finishing this project. The entire results of the XRF analysis are shown in the Table 5, Table 6, Table 7 and Table 8. The result shown is the percentage of each element and compound in the material used.

Elemental

Sand

Table 5: Silica Sand Percentage Elemental

Element	O	Al	Si	P	K	Ca	Ti	Fe	Zr	P_2O_5	K_2O
wt %	52	5.40	40.46	0.439	0.351	0.139	0.503	0.3842	0.1691	1.403	0.422

Quick Lime

Table 6: Quick Lime Percentage Elemental

Element	O	Mg	Si	P	K	Ca	Fe	Sr	SiO_2
wt %	29	1.09	0.052	0.188	0.0249	69.72	0.0226	0.0227	1.196

Compound

Sand

Table 7: Silica Sand Percentage Compound

Composition	Al_2O_3	**SiO_2**	P_2O_5	K_2O	CaO	TiO_2	Fe_2O_3	ZrO_2
wt %	10.2	**86.56**	1.01	0.422	0.194	0.840	0.5493	0.2284

Quick Lime

Table 8: Quick Lime Percentage Compound

Composition	**MgO**	SiO_2	P_2O_5	K_2O	**CaO**	Fe_2O_3	SrO
wt %	**1.81**	0.11	0.430	0.0300	**97.56**	0.0323	0.0269

From this result, we can know the elemental and the composition of the materials throughout finishing this project. The sand that is used throughout this experiment is having 86.56% of silica and the quicklime that is used throughout this experiment is containing 97.56% calcium oxide and 1.81% Magnesia. Based on Industrial Studies & Purveys Unit (1970), sand used must have a SiO_2 content of more than 60% is preferred and lime used must have a CaO contents between 70 – 95 % and content of Magnesia (MgO) should not exceed 1.5%.

4.3 Experiment

4.3.1 Compacting Pressure Experiment

For the first experiment which is to find the optimum compacting pressure that will produce the highest green density. The method use to get the actual green density is using Archimedes method. The result of the compacting pressure of 8000 psi (55.16 MPa) experiment is as shown in the Table 9. The rest of the result can be seen in Appendix b Table 11.

Compacting Pressure = 8000 psi = 55.16 MPa

Table 9: Result of 8000 psi compacting Pressure on Green Density

Test No.	Green Density,(g/cm^3)
1	2.12
2	2.072
3	2.035
Average Green Density	2.076

The overall result of the Compacting Pressure range from 6000 psis (41.37 MPa) to 16000 psi (110.32 MPa) is shown in the Table 10.

Table 10: Result of different compacting pressure on Green Density

Compacting Pressure (psi)(MPa)	Average 3 sample Green Density,(g/cm^3)
6000 (41.37)	2.073
8000 (55.16)	2.076
10000 (68.95)	2.08
12000 (82.74)	2.108
14000 (96.53)	2.110
16000 (110.32)	2.144

The amount of porosity is needed to be calculated to see the effect on compacting pressure on porosity of the sample. To calculate the amount of porosity in the sample, the green density is calculated by the following formula and shown in the Table 13. The overall result of calculated density is shown in Table 12.

Density,

$$\rho = {}^{m}/_{V} \left({}^{g}/_{cm^3}\right)$$

Table 12: Result of different compacting Pressure on Calculated Density

Compacting Pressure (psi)(MPa)	Average 3 sample Calculated Density,(g/cm^3)
6000 (41.37)	2.094
8000 (55.16)	2.095
10000 (68.95)	2.095
12000 (82.74)	2.122
14000 (96.53)	2.122
16000 (110.32)	2.154

Compacting Pressure = 8000 psi = 55.16 MPa

Table 13: Result of 8000 psi compacting Pressure on Calculated density

Test No.	Volume (cm^3)	$W_{after\ compacting}$ (g)	Average 3 sample Calculated Density, (g/cm^3)
1	0.486177422	1.0045	2.066
2	0.478089443	1.002	2.096
3	0.485278758	1.03	2.122
	$\boldsymbol{CalculatedDensity_{Ave}}$		2.095

Example of calculation from Test 1, compacting pressure = 8000 psi (55.16 MPa)

$$Area\ of\ Pallet\ =\ \pi j^2\ = \pi\ (6.55mm)^2\ = 1.33^{-4}m^2$$

$$h\ = 3.587mm\ =\ 3.607^{-3}m$$

$$V = Area\ \times h =\ 1.33^{-4}m^2 \times\ 3.607^{-3}m\ = 4.86177^{-7}m^3$$

$$Calculated\ Density, \rho = \frac{m}{V} = \frac{0.001008}{4.86177^{-7}} = 2069.49\ {}^{kg}/_{m^3} = 2.06\ {}^{g}/_{cm^3}$$

The amount of the porosity of the sample has been calculated based on the formula that been shown below and the result is shown in Table 13. The rest of the result can be seen in Appendix b Table 11.

Porosity,

$$Porosity = \frac{\rho_{measured} - \rho_{actual}}{\rho_{actual}} \times 100\%$$

Table 14: Result of different compacting pressure on Porosity

Compacting Pressure (psi)(MPa)	Average 3 sample Porosity
6000 (41.37)	1.013
8000 (55.16)	0.915
10000 (68.95)	0.721
12000 (82.74)	0.664
14000 (96.53)	0.569
16000 (110.32)	0.466

Example of calculation for compacting pressure 8000 psi (55.16 Mpa)

$$Porosity = \frac{\rho_{measured} - \rho_{actual}}{\rho_{actual}} \times 100\%$$

$$Porosity = \frac{2.095 - 2.076}{2.076} \times 100\%$$

$$Porosity = 0.915$$

Figure 6 : Sample of 6000 psi Compacting Sand Lime Brick

Figure 7 : Sample of 8000 psi Compacting Sand Lime Brick

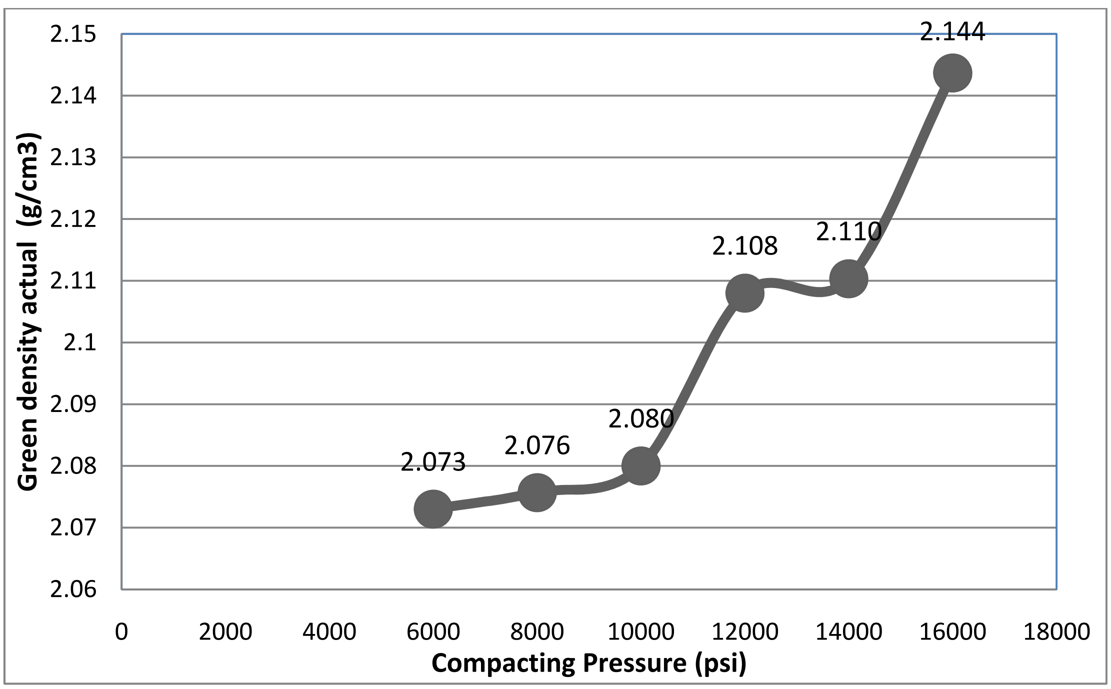


Figure 17 : Green Density vs. Compacting Pressure

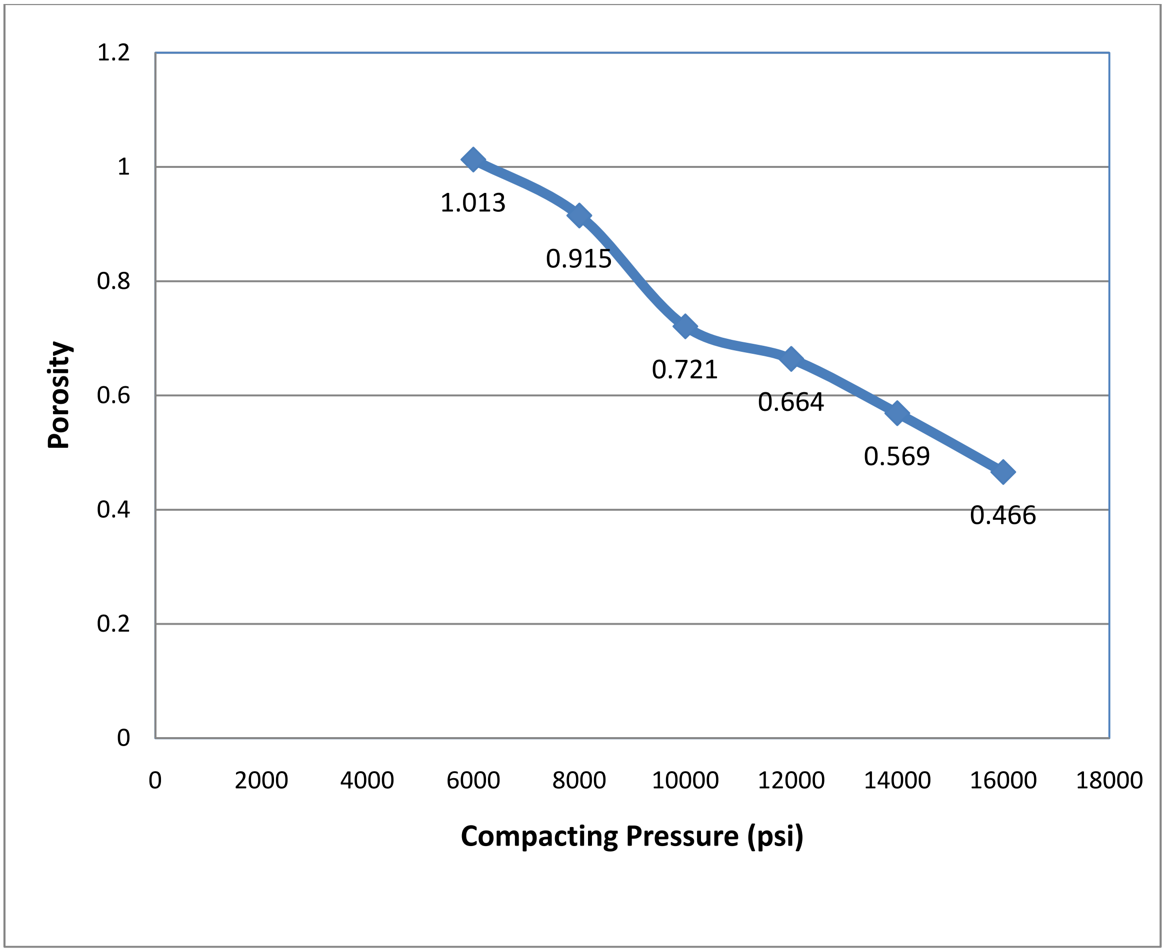


Figure 18 : Porosity vs. Compacting Pressure

An increase trend in green density is observed with the increasing value of compaction pressure used to compact the sample. The amount of porosity of the sample is calculated and the trend is decreasing as the increasing value of compaction pressure. It is because with increasing the compacting pressure, the particle arrangement of material is more compact and more particles filled to the porous part in the sample. It is also verify that the ceramics material shows a good density at higher compacting pressure.

4.3.2 Sintering Temperature Experiment

The second experiment is to find the optimum sintering temperature for the process of making sand lime brick. The actual process is to use the autoclave machine for hardening process, since the machine is not available in UTP. The compacting pressure that been used for this experiment is based on the previous experiment which is finding the optimum compacting pressure. Based on the result, the compacting pressure 16000 psi / 110.32 MPa has shown to produce the highest green density.

For this sintering temperature experiment, the temperature range tested is 200^{o}C, 400^{o}C, 600^{o}, 800^{o}C, 1000^{o}C and 1200^{o}C at 1 hour dwelling time and cooling rate 5^{o}C/min. The overall result of the sintering temperature experiment is shown in the Table 15. The rest of the result can be seen in Appendix b Table 16.

.

Table 15: Result of different Sintering Temperature on Sintered density

Sintering Temperature (^{o}C)	Average 5 sample Sintered Density,(g/cm^{3})
200	2.121
400	2.131
600	2.144
800	2.151
1000	2.161
1200	2.191

The amount of porosity is needed to be calculated to see the effect of different sintering temperature on porosity of the sample. To calculate the amount of porosity in the sample, the sintered density is calculated as follow the same formula and method as shown in compacting pressure experiment. The entire result is shown in the Table 17 and 18. The rest of the result can be seen in Appendix b Table 16.

Table 17: Result of different Sintering Temperature on Calculated Density

Sintering Temperature (^oC)	Average 5 sample Calculated Density, (g/cm3)
200	2.1312
400	2.1404
600	2.1542
800	2.1602
1000	2.1692
1200	2.1984

Table 18: Result of different Sintering Temperature on Porosity

Sintering Temperature (^oC)	Average 5 sample Porosity
200	0.490
400	0.460
600	0.487
800	0.428
1000	0.370
1200	0.329

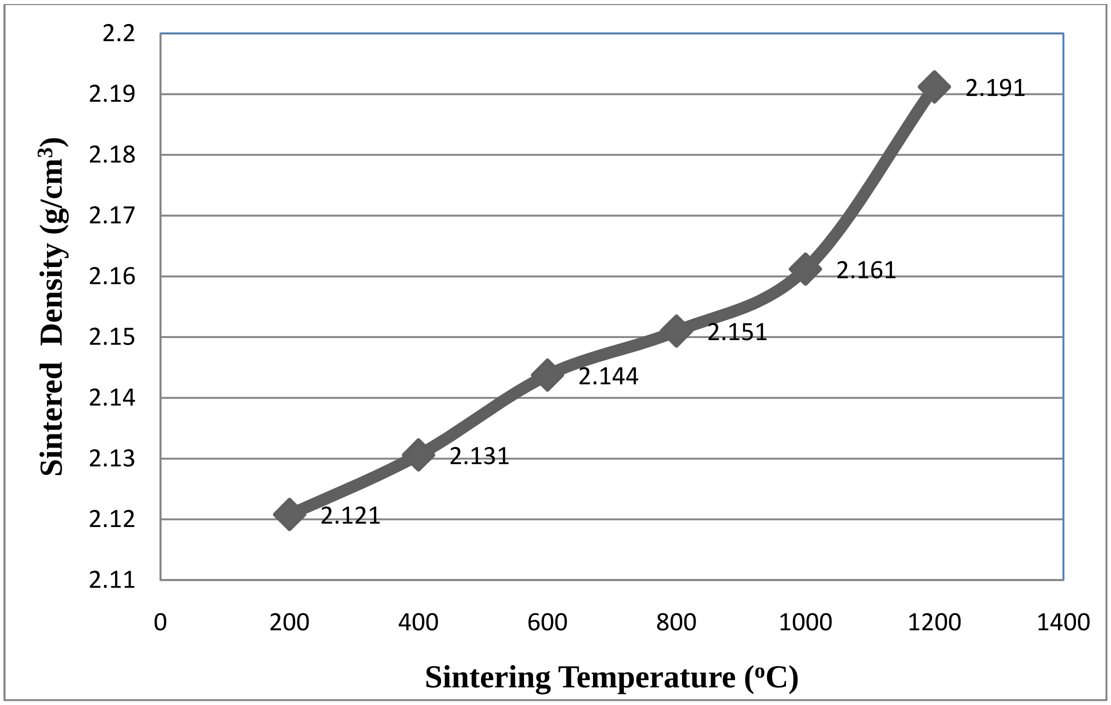


Figure 19: Sintered Density vs. Sintering Temperature

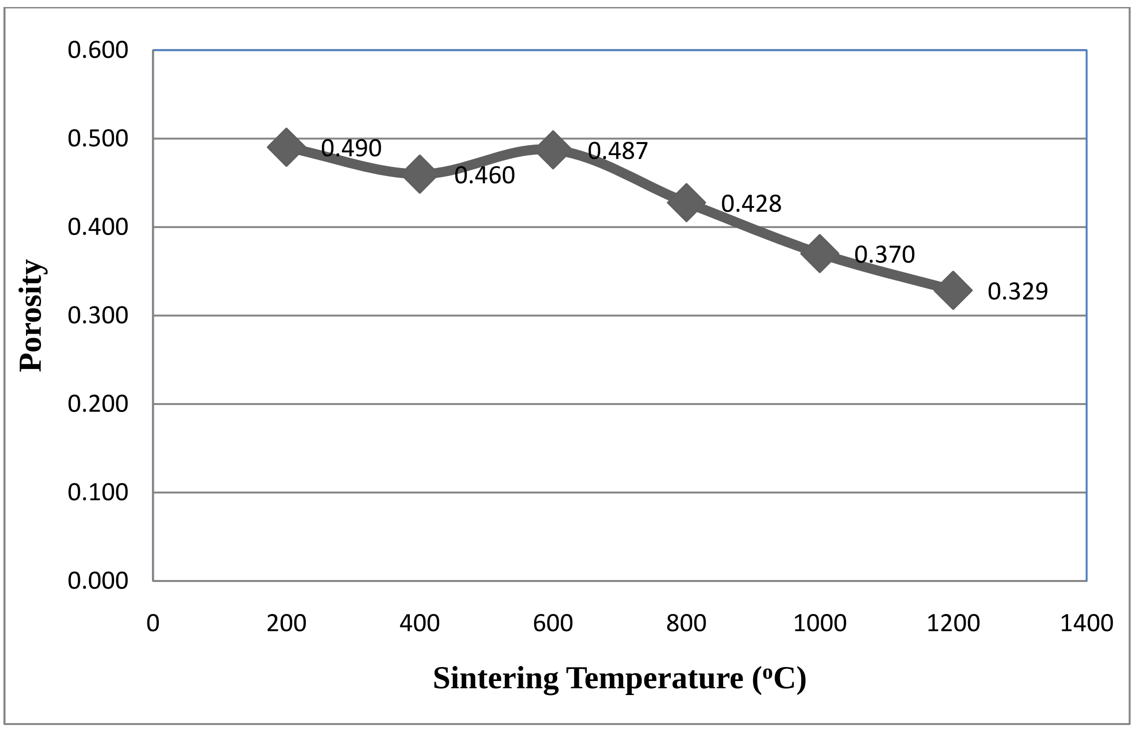


Figure 20: Porosity vs. Sintering Temperature

An increase trend of sintered density is seen with the increasing trend of sintering temperature. As the increasing temperature of sintering, the porosity value of the sample is also reduced. It is due to the most of the porous part in the sample are filled by the silica sand particles to make the sample more dense and the bonding and densification of silica sand and quicklime during the process. The presence of quicklime is seen improving the densification process during sintering and provides better adhesion and bonding between the particles in the sample.

4.3.3 Compressive Test and Water Absorption Test

According to ASTM C73-99a, for the Grade SW, the $CaSiO_2$ must having the physical requirement of compressive strength for an individual brick is 31.0 MPa (4500 psi) and for average 3 bricks; the compressive strength is 37.9 MPa (5500 psi) and water absorption for the brick is 240 kg/m^3 (15 lb/ft^3).

However, our composition is $CaO + SiO_2 + H_20$ and processing method is powder processing root and sintering process which is different from the actual method which is using compacting mixture of sand, quicklime and water and hardening in Autoclave.

The sample is tested with using Universal Testing Machine 100 kN. The sample is crushed by the machine to get the compressive strength. The result of the compressive test is shown in the Table 19. The graph get from the compressive test is provided in the Appendix c Figure 21, 22 and 23.

Table 19: Result of Compressive Test

Sample no	Compressive Force (kN) individual	Area (m^2)	Compressive Pressure (MPa)	Average 3 Compressive Pressure (MPa)
3	7.94	0.0001395	56.9155901	60.39775
4	8.67	0.0001395	62.1483836	
5	8.65	0.00013923	62.129278	

Example Calculation of Compressive Strength of Sample no 3

$$Compressive\ Force = 7.94\ kN$$
$$Area_{sample\ 3} = 0.0001395m^2$$
$$Compressive\ Pressure = F/A$$
$$Compressive\ Pressure = 7.94\ kN \div 0.0001395$$
$$Compressive\ Pressure = 56.9155901\ MPa$$

Based on the sample's compressive test result, the compressive strength of 1 sample and average 3 samples made meet the ASTM requirement of SW bricks. It is due to the size of particle used and method of producing the sample which is powder processing root. Since the average particle size of SiO_2 used for the sample is less than 150µm and the method of producing the sample with high compacting pressure and high sintering temperature, the SiO_2 particle is filled to the porous part in the sample and makes the sample to have more compressive strength.

As for water absorption test, the sample is immersed into water for 24 hours in order to calculate the amount of water absorption of the sample. The result of the tested sample is shown in the Table 20.

Table 20: Result of Water Absorption Test

Sample	mass before immersed in water (g)	mass after immersed in water (g)	Volume (cm3)	Water Absorption (g/cm3)	Water Absorption (kg/m3)
1	0.926	0.963	0.493	0.0810	81.05
2	0.914	0.951	0.490	0.0826	82.62

The formula for calculating the amount of water absorption is as follows.

Water Absorption,

$$Water\ absorption = \frac{\left(m_{after\ immersed\ in\ water} - m_{before\ immersed\ in\ water}\right)}{m_{before\ immersed\ in\ water}}\,(kg/m^3)$$

Example Calculation of Water Absorption Sample 1

$$Water\ absorption = \frac{\left(m_{after\ immersed\ in\ water} - m_{before\ immersed\ in\ water}\right)}{m_{before\ immersed\ in\ water}}$$

$$Water\ absorption = \frac{(0.96266 - 0.92567)}{0.92567}$$

$$Water\ absorption = 0.0810\ g/cm^3$$

$$Water\ absorption = 81.05\ kg/m^3$$

Based on the water absorption test, the water absorption value is lower than the ASTM standards which is 240 kg/m^3(15 lb/ft^3). It is due to the SiO_2 particle is filled to the porous part in the sample and makes the sample the less porosity that could let the water to flow into the sample. It is also because silica is less absorbent of water. It proves that the amount of water which is trapped in the sample is lower than the ASTM requirement.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The project will give the student to study on the effect of varying the compacting pressure and sintering temperature in a process of making sand lime brick. It is important to study this project since the material used can be found around of us such as UTP's lake and can help in founding the best way to produce sand lime brick.

As for conclusion, with increasing the compacting pressure of sample from 6000 psi (41.37 MPa) to 16000 psi (110.32 MPa), it shows an increasing trend of sample's green density from 2.073 g/cm^3 to 2.144 g/cm^3 with shows increment of 3.42% of green density and decreasing amount of porosity of the sample from 1.013 to 0.466 with shows increment of 117.38%. It is due to particle arrangement is more compact and more particle filled to the porous part in the sample and it shows that ceramics material shows a good density at higher compacting pressure.

As for sintering temperature experiment, as increasing sintering temperature from 200 ^{o}C up to 1200 ^{o}C result in increasing of sintered density from 2.121 g/cm^3 to 2.191 g/cm^3 with shows increment of 3.3% and decrease amount of porosity in the sample from 0.490 to 0.329 with shows decrement of 48.9%. The sintered density is increase from green density by 2.19%. This proves that increasing sintering temperature and presence of quicklime is seen improving the densification process during sintering and provides better adhesion and bonding between the particles in the sample.

As for compressive test and water absorption test, sample from compacting pressure 16000 psi and sintering temperature 1200^{o}C has resulted of 60.4 MPa compressive strength for average 3 bricks and 81.05 kg/m^3 water absorption test. The result shows a higher value of compressive strength and lower value of water absorption than required ASTM. It is due to the size of particle used and method of producing the sample which is powder processing root.

With all the observations produces during the project, it can be concluded that with increasing compacting pressure and sintering temperature has will improve the density, porosity, compressive strength and water absorption of the mixture of sand lime brick.

5.2 Recommendations

For further study, recommendations are based on 3 main things which are:

1. Mixture
   a. The mixture of silica sand, quicklime and water used throughout this experiment is 76 wt% Silica Sand, 13wt% Quicklime and 11wt% Water. For further study, the mixture composition can be change to see the effect of mixture composition on the properties of sample.

2. Compaction Pressure
   a. The compaction pressure tested for this experiment is range between 6000 psi (41.37 MPa) to 16000 psi (110.32 MPa). For further study, the compacting pressure should be increase to see the result of higher compacting pressure to green density of the sample.

3. Sintering Temperature
   a. The sintering temperature tested for this experiment is range between 200 ^{o}C and 1200 ^{o}C. For further study, the sintering temperature should be increase to see the result of higher sintering temperature to sintered density of the sample.

REFERENCES

The format of references for the respective sources is as follows

1. Technical report refers to Immo (1969).
2. Technical report refers to Industrial Studies & Purveys Unit (1970).
3. Standards refer to ASTM Standards, Vol. 04.02 C73-99A.
4. Book refers to Samuel (1912).

Immo H. Redeker, 1969. *Possible Production of Calcium Silicate Building Products from Feldspar Plant Tailing.* North Carolina State University, Mineral Research Laboratory Asheville, North Carolina.

Industrial Studies & Surveys Unit, 1970. *A preliminary project report on Sand Lime bricks.* Federal Industrial Development Authority

Annual Book of ASTM Standards 2004, Vol. 04.02 C73-99A, Standard specification for Calcium Silicate brick (Sand Lime Brick)

Samuel Wilson Parr 1912, *A Study of Sand Lime Brick.*

APPENDIX A


8


9

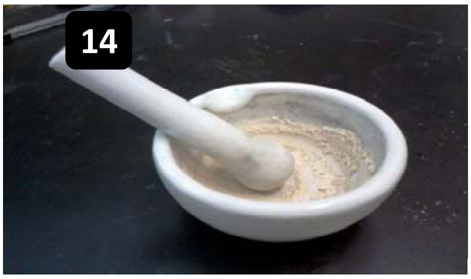

10
1000AII


11
Ball Mill


12


13


16


14


15
CARVER
Autopallet Press Machine

APPENDIX B

Table 11: Result of different compacting pressure on Green Density, Calculated Density and Porosity

Compacting Pressure (psi) MPa	sample	sample mass (g)	Volume (cm3)	Calculated Density (g/cm3)	Average Calculated Density (g/cm3)	Green Density (g/cm3)	Average Green density (g/cm3)	Average Porosity
6000 (41.37)	1	1.015	0.483481429	2.161406699	2.094	2.103	2.073	1.013
	2	1.035	0.495164066	2.090216296		2.085		
	3	1.023	0.477005360	2.127882601		2.049		
	4	0.977	0.488873415	1.998472343		2.055		
8000 (55.16)	1	1.0045	0.486177422	2.066000032	2.095	2.12	2.076	0.915
	2	1.002	0.478089443	2.096000261		2.072		
	3	1.03	0.485278758	2.122000016		2.035		
10000(68.95)	1	1.008	0.487076087	2.069491867	2.095	2.04	2.080	0.721
	2	0.989	0.477190779	2.072546336		2.107		
	3	0.895	0.417878931	2.141768667		2.093		
12000(82.74)	1	0.963	0.463710813	2.076725348	2.122	2.132	2.108	0.664
	2	1.011	0.484380094	2.087203858		2.057		
	3	1.025	0.465508142	2.201894892		2.135		
14000(96.53)	1	1.018	0.477190779	2.133318676	2.122	2.106	2.110	0.569
	2	1.014	0.477190779	2.124936284		2.12		
	3	1.015	0.481684101	2.107190166		2.105		
16000(110.32)	1	0.9818	0.468204135	2.096948588	2.154	2.179	2.144	0.466
	2	0.9743	0.416081602	2.341607982		2.165		
	3	0.9505	0.470001464	2.022334127		2.087		

APPENDIX B

Table 16: Result of different sintering temperature on Sintered Density, Calculated Density and Porosity

Sintering Temperature (^oC)	sample	sample mass (g)	Volume (cm3)	Calculated Density (g/cm3)	Average Calculated Density (g/cm3)	Sintered Density (g/cm3)	Average Sintered density (g/cm3)	Average Porosity
200	1	0.9758	0.461522163	2.114307997	2.1312	2.078	2.121	0.49038099
	2	0.9719	0.459252266	2.116266094		2.165		
	3	0.9728	0.457386337	2.126867203		2.104		
	4	0.9695	0.453336759	2.138586782		2.134		
	5	0.9725	0.449772714	2.156644833		2.123		
400	1	0.9574	0.460815955	2.077619036	2.1404	2.123	2.131	0.45996433
	2	0.9899	0.449314814	2.203132347		2.198		
	3	0.9752	0.457852463	2.129943765		2.131		
	4	0.9742	0.457885849	2.127604517		2.127		
	5	0.9985	0.461522163	2.163493067		2.074		
600	1	1.0376	0.465753055	2.227790006	2.1542	2.108	2.144	0.48746356
	2	0.9965	0.466308713	2.136996313		2.114		
	3	0.9986	0.477498951	2.091313495		2.182		
	4	1.0236	0.473741776	2.160670752		2.171		
800	1	1.0909	0.503588725	2.166251834	2.1602	2.153	2.151	0.42770804
	2	1.0897	0.501050813	2.174829324		2.24		
	3	1.0895	0.505944494	2.153398273		2.132		
	4	1.0986	0.510744727	2.150976687		2.12		
	5	1.0989	0.50978468	2.155615974		2.11		

1000	1	1.0256	0.466224345	2.199799325	2.1692	2.344	2.161	0.37016472
	2	1.0136	0.465753055	2.176260553		2.366		
	3	0.9986	0.463433697	2.154785045		2.05		
	4	1.0143	0.46709951	2.1714859		2.048		
	5	1.0123	0.472206441	2.143765762		1.998		
1200	1	1.0697	0.492859422	2.170395762	2.1984	2.063	2.191	0.32858708
	2	1.0785	0.490020088	2.200930177		2.057		
	3	1.0699	0.493847116	2.166459955		2.29		
	4	1.0977	0.493847116	2.222752681		2.144		
	5	1.0998	0.492859422	2.231467944		2.402		

APPENDIX C

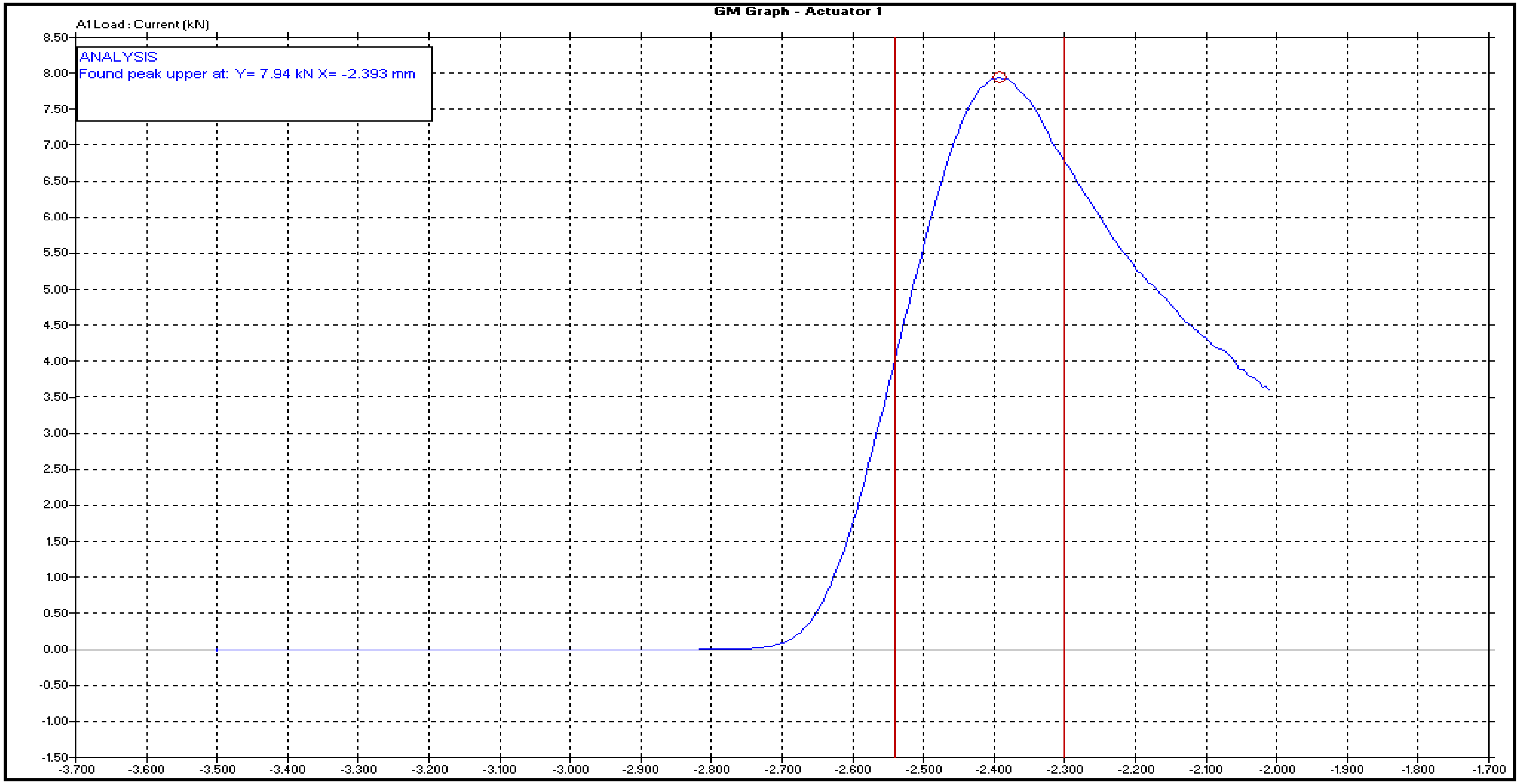

GM Graph - Actuator 1
A1 Load : Current (kN)
ANALYSIS
Found peak upper at: Y= 7.94 kN X= -2.393 mm
8.50
8.00
7.50
7.00
6.50
6.00
5.50
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
-3.700
-3.600
-3.500
-3.400
-3.300
-3.200
-3.100
-3.000
-2.900
-2.800
-2.700
-2.600
-2.500
-2.400
-2.300
-2.200
-2.100
-2.000
-1.900
-1.800
-1.700

Figure 21: Compressive Test Result Sample no. 3

APPENDIX C

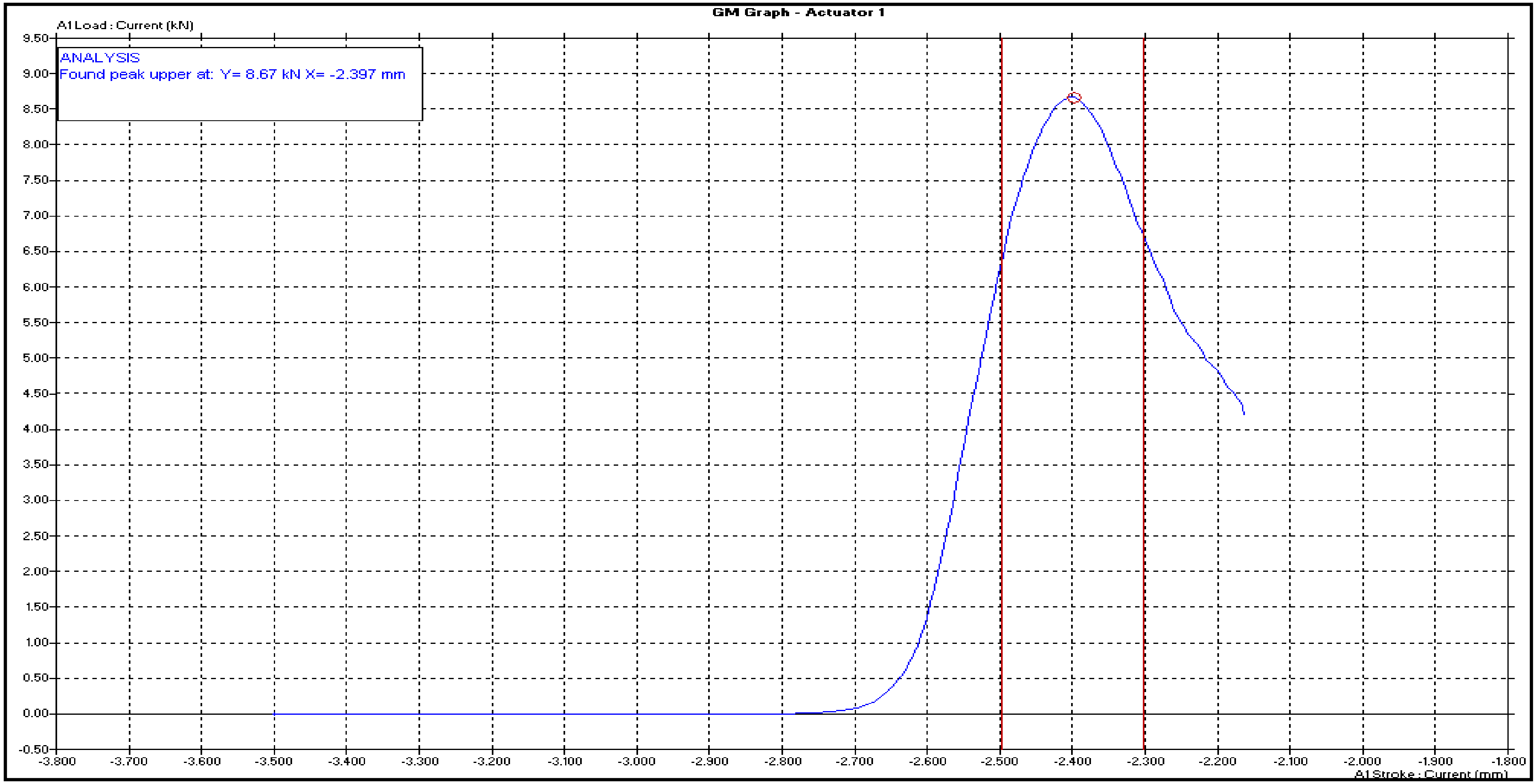


Figure 22: Compressive Test Result Sample no. 4

APPENDIX C

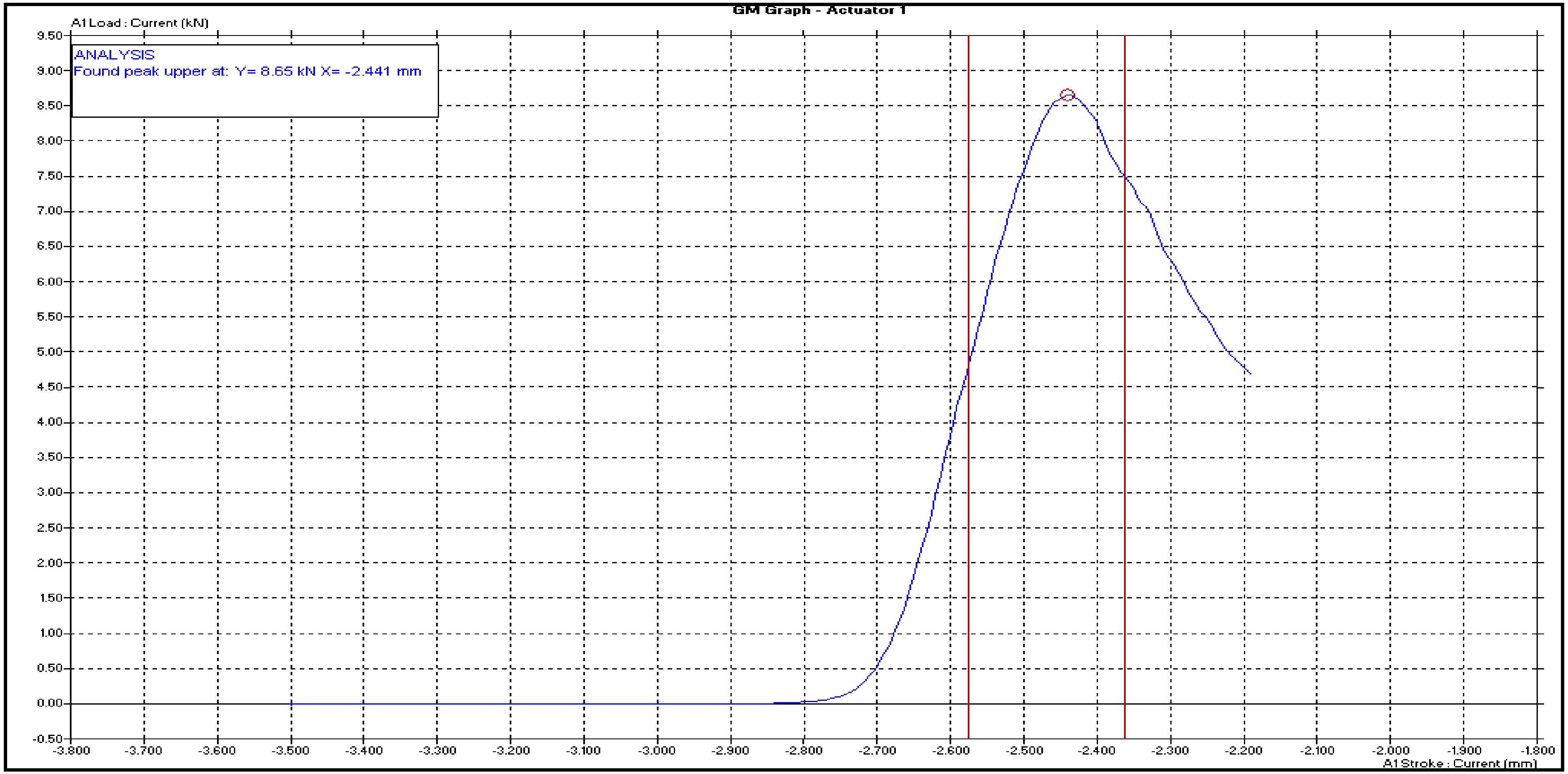


Figure 23: Compressive Test Result Sample no. 5